Economic Analysis of the January 2001 California Department of Pesticide Regulation Regulations on Strawberry Field Fumigation

Report prepared for the California Department of Food and Agriculture

Colin A. Carter, James A. Chalfant, and Rachael E. Goodhue*

Department of Agricultural and Resource Economics
University of California, Davis

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* Colin A. Carter and James A. Chalfant are Professors in the Department of Agricultural and Resource Economics, University of California, Davis, and members of the Giannini Foundation of Agricultural Economics. Rachael E. Goodhue is an Assistant Professor in the Department of Agricultural and Resource Economics, University of California, Davis, and a member of the Giannini Foundation of Agricultural Economics. Chalfant is also department chair. Carter is also an Associate Director (for International Trade) of the UC Agricultural Issues Center. We wish to thank Leo Simon for very helpful discussions and the use of his MATLAB program for optimal fumigation plans. We also wish to thank Kim Brobeck, Massimiliano de Santis, Kristiana Hansen, Greg McKee, Jennifer Thompson, and Tian Xia for research assistance, and Kim Brobeck for assistance with figures.

EXECUTIVE SUMMARY

The California Department of Pesticide Regulation (DPR) introduced methyl bromide (MeBr) application regulations, effective January 2001. These regulations had a measurable and significant impact on California agriculture and they remain controversial. The purpose of this report is to estimate the economic effects of the 2001 DPR regulations on the California strawberry industry. Our overall conclusion is that the regulations were quite costly to strawberry growers, and the effects were unevenly distributed across farmers and regions. We estimate that the total cost to the industry exceeded $25 million in 2001, or roughly 25% of estimated industry returns over total cash costs of $103.7 million.

In order of priority, the main economic impacts of the 2001 regulations were

- Foregone profits from sales of processing berries, due to a reduction in the season length ($10.4 million);
- Added labor, machinery, and other costs due to a longer fumigation period ($10 million);
- Added fumigation costs due to switching away from bed fumigation to flat fumigation ($2.4 million);
- Increased costs due to inability to fumigate with methyl bromide in the acreage comprising inner buffer zones ($3.2 million); and
- Notification costs ($125,000).

A recent court ruling (San Francisco Superior Court, Case No. CGC-01-318270) underscored the controversial nature of the regulations. The outcome of the Court case makes it unclear whether these regulations will be changed for 2002 and beyond. Although the 2001 regulations have been set aside by the Court, the January 2001 regulations were in effect for one season, and they will likely serve as a starting point for the development of new regulations for 2002. A stay has been granted until September 2002, at which time DPR is expected to issue emergency regulations.

In 1992, the Montreal Protocol (a group of more than 150 nations that have agreed to protect the ozone layer) declared MeBr an ozone-depleting chemical. The Montreal Protocol triggered provisions under the U.S. Clean Air Act, and, as a result, the U.S. Environmental Protection Agency (EPA) took regulatory action and determined that the quantity of MeBr sold in the United States (from either domestic or foreign sources) would be reduced to 50% of 1991 levels by 2001, and then totally eliminated by 2005. Where possible, this report attempts to isolate the effects of the California 2001 DPR regulations from the U.S. EPA phase-out requirements. As of 2001, the main effect of the phase out requirements on strawberry growers was a higher price for MeBr. Overall MeBr usage in California strawberry production had not yet declined by 2000, and remained above 4 million pounds. Given that strawberry growers had not yet switched away from using MeBr, the cost of the 2001 DPR regulations was relatively high.

The DPR state-level regulations were aimed at reducing human exposure to MeBr. For each fumigation site, the DPR regulations stipulated dual buffer zones where MeBr could not be applied to the soil. The buffer zones depended on such factors as application rate (i.e., pounds of MeBr per acre), method of application, and proximity of the site to schools, houses, hospitals, or other occupied buildings. In addition, the DPR regulations contained worker hour restrictions, and required strawberry growers to notify neighbors within 300 feet of the outer buffer regarding their intent to fumigate with methyl bromide, and, if the neighbor requested, an additional notification 48 hours prior to MeBr fumigation.

The 2001 regulations essentially forced some growers to either shut down their strawberry operation or use alternative fumigation procedures that may not be as effective at controlling pests. With the 2001 regulations in place, grower costs increased because, in many cases, it took three to four times longer to fumigate each field. Additional worker and machinery time were required under the 2001 regulations. The extended fumigation period also reduced revenue from the processing market from the 2000 crop. The old crop plants had to be removed earlier than normal in order to prepare the fields for the lengthy fumigation period. In addition, some growers had no choice but to change their method of fumigation and hire commercial applicators. In some cases, more irrigation was needed for fumigant application. The DPR regulations imposed a relatively higher cost on growers with smaller fields, especially those on the urban fringe.

The regulations increased the time necessary for fumigation for many fields, and increased the time spent by most growers in complying with the regulations. Further, many of the economic costs of the use regulations were unequally distributed across growers. Growers with small fields faced a proportionately larger acreage loss due to buffer zones than growers with large fields, holding other factors constant. Growers in areas of high population densities faced higher costs associated with permission notification and buffer zone requirements. Growers in the southern part of the state likely lost more profit per acre than their counterparts in the northern growing regions due to foregone sales into the processing market at the end of the 2000 crop.

I. PROJECT OBJECTIVES

The goal of this project was to estimate the economic impacts of the January 2001 California DPR regulations on California strawberry producers at the field and industry levels. The project tasks included the following:

- Estimate strawberry cost of production budgets for the Oxnard, Orange County, and Watsonville commercial production regions;
- Estimate the share of acreage affected by the DPR's minimum buffer zone requirements and regional differences of these impacts;
- Estimate farm-level costs of the DPR regulations, including notification costs and value of foregone sales of processing berries;
- Estimate overall industry level costs of the DPR regulations and regional differences in costs and revenue impacts. Assess the competitive position of California strawberry producers, within the state and relative to competitors.

II. BACKGROUND

The strawberry industry is an important component of Californian agriculture. In 2001, over 25,000 acres were planted to strawberries in the state, and California's total strawberry sales to both the fresh and processed markets were $805.8 million (see Table 1). In a typical year, strawberries rank as one of the top ten most valuable crops in the state (CDFA, *Resource Directory*, 2001). The leading counties in value of strawberry production are Monterey (30.2%), Ventura (24.7%), Santa Cruz (16.8%), Orange (10.7%), and Santa Barbara (10%), together representing over 90% of the total volume of production.

California leads the U.S. strawberry industry. Currently, the state accounts for over 80% of the 1.8 billion pounds produced in the United States. Florida is the second largest producing state, with about 12% of national production. California's dominance of the national strawberry market is due to the combination of three factors: (1) a greater number of planted acres; (2) substantially higher yields than other production areas; and (3) a significantly longer harvest season, due to the favorable climate.

In 2001, California strawberry growers harvested 1.3 billion pounds of strawberries (see Table 1). Strawberries are the fourth most valuable fruit crop produced in the United States, following grapes, apples, and oranges. (California Strawberry Commission, 2001 http://www.calstrawberry.com/facts/industry.asp). Based on the University of California cost and returns budgets for strawberries included as Appendix 3, net grower returns above total cash costs are roughly $103.7 million.

Table 1. California Strawberry Industry: Summary Statistics

Year	Acres (thousands)	Production (billion lbs.)	Yield (thousand lbs. per acre)	Fresh (%)	Freezer (%)	Fresh value (m$)	Frozen value (m$)	Total farm value (m$)
1991	21.1	1.10	52.133	69.7%	30.3%	389.5	76.0	465.5
1992	24.0	1.03	42.917	73.9%	26.1%	451.7	61.3	513.0
1993	25.1	1.14	45.418	67.7%	32.3%	362.0	95.8	457.9
1994	23.3	1.33	57.082	67.9%	32.1%	532.8	114.7	647.6
1995	23.6	1.30	55.085	69.7%	30.3%	519.4	92.0	611.4
1996	25.3	1.36	53.755	73.4%	26.6%	524.4	60.4	584.9
1997	22.6	1.33	58.850	72.1%	27.9%	590.5	95.9	686.4
1998	24.2	1.36	56.198	67.0%	33.0%	624.2	132.6	756.8
1999	24.6	1.51	61.382	66.6%	33.4%	718.7	157.5	876.2
2000	27.6	1.52	55.072	72.4%	27.6%	674.7	92.6	767.3
2001	25.1	1.27	50.598	74.3%	25.9%	709.1	96.7	805.8

Source: CDFA 2001 Agriculture Resource Directory (www.cdfa.ca.gov)
Note: 2001 data from 2001 Annual Report, Processing Strawberry Advisory Board of California

The trends shown in Table 1 indicate that the industry has grown since 1991 with acreage rising rapidly between 1991 and 1993, and fluctuating thereafter until rising in 2000, to 27,600 acres. Acreage planted declined in 2001, as did production. Yields do not show a clear trend, although they fell somewhat each time there was a large increase in planted acreage, and fell further along with the reduction in planted acres in 2001. One strategy for investigating the effects on acreage and yield of the DPR regulations would be to attempt to estimate jointly the effects on acreage and production from the regulations and any other changes, such as market prices. For instance, there appears to have been reduced demand for processing berries in both 2000 and 2001, perhaps due to a buildup of frozen stocks in 1999; one thus cannot attribute every development in 2001 to the DPR regulations. Instead of separating such trends, our report attempts to calculate the costs of the regulations directly, and the industry trends provide a background against which to judge these costs.

Statistics in Table 2 from the latest agricultural census (in 1997) indicated that there were 831 farms producing strawberries in California, with an average size of 21 acres of all berries per grower (1997 U.S. Census of Agriculture). Measured by acreage, most producers are relatively small, with less than fifty acres of strawberries. In 1997, 80% of the strawberry farms were 50 acres or smaller. There are, however, a few integrated and partially integrated operations that manage hundreds of acres. Table 2 reports farm size by the total value of crop sales in 1997. The figures shown in the table are suggestive of the present size distribution of farms, but the dollar figures are inconsistent with cost data in University of California budgets, and with revenue figures reported by the Processing Strawberry Advisory Board and CDFA.

Table 2. California Farms Growing Strawberries (Number and Acreage) by Total Value of Crop Sales

Total Value of Crop Sales	Less than $10,000	$10,000 to $24,999	$25,000 to $49,999	$50,000 to $99,999	$100,000 to $499,000	More than $500,000	Total
Number of farms	196	103	127	90	149	166	831
Land in farms	2,836	954	2,638	1,803	9,527	58,159	75,917
Average farm size	14	9	21	20	64	350	91
Cropland harvested	824	511	1,405	1,160	6,453	40,536	50,889
Average cropland	4	5	11	13	43	244	61
Average acres in all berries	2	3	4	5	15	80	21

Source: Agriculture Census for California, 1997

Compared to all other crops, per acre production costs for strawberries rank among the highest in the state. The crop is labor intensive and the season lasts for several months. These two reasons alone explain a large share of the high costs of production. Given the labor-intensive nature of strawberry production, approximately 48,000 people are employed in the state's strawberry industry (California Strawberry Commission, 2001 http://www.calstrawberry.com/facts/industry.asp). Every year, growers risk almost $30,000 per acre to produce strawberries, so even a 30-acre farm has an outlay of about $1 million per year to produce and harvest the crop.

Methyl bromide (MeBr), a soil fumigant, is highly effective in controlling weeds and nematodes in California's strawberry fields. Strawberry growers, by far the largest MeBr users in the state, applied about 4.2 million pounds of MeBr in 2000, accounting for almost 40 percent of the statewide usage (see Table 3). On average, close to 200 pounds of MeBr are applied to each acre of strawberries (California Department of Pesticide Regulation website http://www.cdpr.ca.gov).

Table 3. Methyl Bromide Usage in California: 1996-2000

Year	Total MeBr applied in California (lbs.)	MeBr applied to strawberries (lbs.)	Strawberries share of MeBr usage	Total California strawberry acreage using MeBr	Lbs. MeBr applied per acre of strawberries
1996	16,022,069	4,383,611	27%	21,345	205
1997	15,663,832	4,050,264	26%	21,746	186
1998	13,569,875	4,257,364	31%	20,291	210
1999	15,342,080	5,175,568	34%	25,493	203
2000	10,862,836	4,234,905	39%	22,580	188

Source: CDPR, 2002. 2001 PUR data were unavailable on the CDPR website, 6/24/02

III. 2001 FUMIGATION REGULATIONS

For each strawberry field treated with MeBr (i.e., for each fumigation site), the 2001 DPR MeBr regulations stipulated dual buffer zones that depend on such factors as application rate, method of application, proximity of the field to houses or other occupied buildings, and the willingness of neighbors to allow the fumigation to proceed. The buffer zone requirements impose a relatively higher cost on growers with smaller fields, especially those in urbanized areas. For instance, a strawberry grower with a 10-acre square field in the middle of an urban area would lose a minimum of 30% of his acreage due to buffer zone requirements, whereas his counterpart in the same region with a 20-acre square field would lose a minimum of about 21% of his acreage due to proximity to the housing development.

The DPR use restrictions were quite complex. Two types of buffer zones were specified: an *inner* buffer zone and an *outer* buffer zone. Both were designed to protect farm workers and members of the public from acute short-term exposure to methyl bromide. The inner buffer zone extended a minimum of 50 feet from the edge of the application bloc. Only individuals involved in the fumigation process were allowed into the inner buffer zone. These individuals were subject to additional requirements regarding the maximum exposure times for various fumigation tasks. The inner buffer zone had to be on agricultural land, or on a public roadway.

The outer buffer zone was at least 60 feet from the edge of the bloc. People were allowed into the outer buffer zone for transit purposes, or to “conduct activities approved by the county agricultural commissioner.” Here, individual exposure was limited to no more than 12 hours out of any 24. The outer buffer zone was not limited to agricultural land, but could extend into other property, with the exception of occupied housing, schools, hospitals, and other sensitive sites.

For both types of buffer zones, the operator had to obtain permission from the neighboring landowner in order to extend the buffer zone onto his property. In addition to the buffer zone requirements, the 2001 DPR regulations limited total acreage for a single fumigation bloc to 40 acres in any 24-hour period. Since the minimum buffer zone requirements increased with the total acreage fumigated, in many cases the effective fumigation bloc was much smaller.

Overall, these 2001 requirements increased the number of days required to complete the fumigation of a field. There were substantial notification requirements included in the regulations and restrictions on work hours for applicators. Properties within 300 feet of the outer buffer zone were to be notified of the methyl bromide fumigation. As a package, these 2001 regulations lengthened and complicated the fumigation process and reduced the profitability of growing strawberries.

IV. METHYL BROMIDE WORKSITE PLANS

Prior to fumigating in 2001, strawberry growers had to obtain permission from their County Agricultural Commissioner. Each Commissioner required growers to first submit a worksite plan that eventually became part of the fumigation permit. Once the worksite plan was approved and a permit issued, the grower had to notify the Commissioner 48 hours before starting fumigation. The worksite plan included a map of the site (and neighboring properties), application rate and method, emission ratio, and inner and outer buffer zones. In addition, the worksite plan included a notification log and a tarp repair and removal plan. See Appendix 2 for copies of the worksite plan forms used in 2001 in the various counties.

To aid us in evaluating the costs of the DPR methyl bromide fumigation regulations for the California strawberry industry, we collected copies of available completed 2001 fumigation permits and methyl bromide worksite plans for strawberry fields in the five largest strawberry-producing counties measured by product value: Monterey, Orange, Santa Barbara, Santa Cruz, and Ventura. As a group, these five counties account for 92 percent of the value of strawberries produced in California in 2000 (CDFA Resource Directory, 2001). In total we collected more than 400 worksite plans and permits.

For each field, we tabulated permit and field numbers, and field acreage. Field dimension information was included for fields that could be analyzed using the fumigation computer program discussed below. Each field was categorized by shape. Permit information regarding chemicals applied, the methyl bromide application rate, emission ratios and rates, permit inner buffers, binding buffers that reduced acreage, and the number of notifications was entered when reported.

Unfortunately, the work site plan and permit data varied in quality across counties, especially for the purposes of the fumigation computer program that we used in this study. Appendix One discusses these variations in data quality. Further, differences in the permitting process made it difficult to evaluate whether or not we had collected all permits and workplans for a given county. Table 4 summarizes the permit information collected by county. The low total acreage fumigated in 2001, relative to total 2002 strawberry acreage, suggests that in addition to the use of alternatives, some permits and methyl bromide workplans are not included in our analysis.

Table 4. Summary: County Methyl Bromide Fumigation Permit Applications: 2001

	Monterey	Orange	Santa Barbara	Santa Cruz	Ventura	Total
Number of entities applying for permits	69	22	39	32	42	204
Number of fields	134	44	80	64	99	421
Total acreage in permits	5,401	1,484	2,824	1,799	5,984	17,492

Source: Compiled from individual permits collected from County Agricultural Commissioners

V. IMPACTS OF REGULATIONS

Our analysis of the cost to growers of the DPR regulations used of the fumigation permit applications described in the previous section, simulations that we conducted for representative fields, and anecdotal information from formal and informal interviews. We did not conduct a survey designed to generate a random sample of growers that would represent the entire industry. We interviewed officials in the office of the agricultural commissioner in each of the five counties analyzed, experts in the industry, and a small number of growers whom we contacted or who participated in CSC field days and responded to our presentations. Thus, the cost figures reported in this section are reasonable estimates, but not statistically generated. Rather than conduct a sensitivity analysis that might substitute for a confidence interval around our estimates, we report how we calculate each component of the total cost of the regulations, so that the effects of alternative assumptions on industry costs can easily be explored.

V.1. Buffer Zones: Conceptual Framework

Inner Buffer Zones

A notable impact of the DPR regulations on growers was that some acreage could no longer be fumigated with methyl bromide. Inner buffer zones could not extend onto adjacent non-agricultural properties, and could extend onto adjacent agricultural properties only with the permission of the adjoining property owner. If a neighboring property was non-agricultural, or if permission was not granted, then part of the field could not be fumigated. This impact varied by location and field shape.

To conceptually illustrate the basic impacts of the buffer zone requirements, the differential effects of the buffer zone regulations for three different shapes are illustrated in Figure 1, for a representative 10-acre field. In Figure 1, Shape A is a square field (660 feet $\times$ 660 feet), shape B is a rectangular field (933.4 feet $\times$ 466.7 feet), and shape C is also rectangular (466.7 feet $\times$ 933.4 feet). Assume that each field borders non-agricultural property on only one side, the top edge of the field.

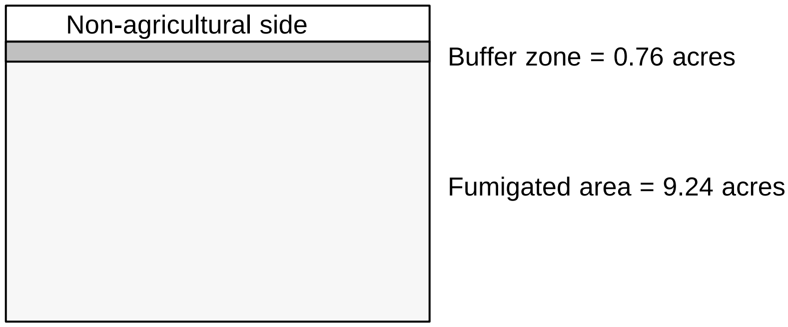
The acreage calculations in Figure 1 are for an application of pure methyl bromide of 200 pounds per acre, using flat fumigation. Roughly, 200 pounds of pure methyl bromide is equivalent to 350 pounds of a 57:43 methyl bromide/ chloropicrin application mix. These assumptions ensure that the inner buffer zone does not extend beyond the minimum 50 feet bordering the non-agricultural side. As shown in Figure 1, the effects of the 50-foot buffer are greatest for field shape B, with the longer side bordering a non-agricultural use. As a result of this loss, over 10% of field shape B's acreage could not be fumigated with methyl bromide, roughly twice the loss of field shape C. The square field shape A represents the intermediate case.

An additional set of calculations helps to illustrate the combined effects of acreage and field shape. Refer to Table 5, which reports the share of total acreage that could not be fumigated with methyl bromide under the January 2001 buffer zone regulations. Table 5 was constructed using the following assumptions: Application rate is 200 pounds/acre. Flat fumigation emission ratio is 0.4. Bed fumigation emission ratio is 0.8. Maximum fumigated acres: 15 acres/day. The table shows the minimum percentage acreage loss for fields of different sizes (10, 50, and 100 acres), different shapes (shapes A, B, and C as in Figure 1), and using different fumigation methods (flat versus bed). Table 5 was constructed under the assumption that the optimal fumigation plan with the smallest acreage loss was used.

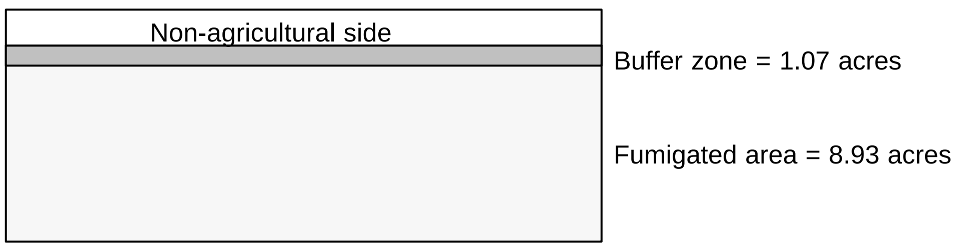
Table 5 reports buffer zone acreage with five alternative non-agricultural border configurations. The first configuration is one non-agricultural border (as in Figure 1). The first row in Table 5 (representing flat fumigation of a ten acre field with one non-agricultural border) thus contains the same information as in Figure 1. The second row in Table 5 represents the same field but assumes bed fumigation, and so on.

Figure 1. Hypothetical Acreage Loss Due to 50' Buffer and 10 Acre Field

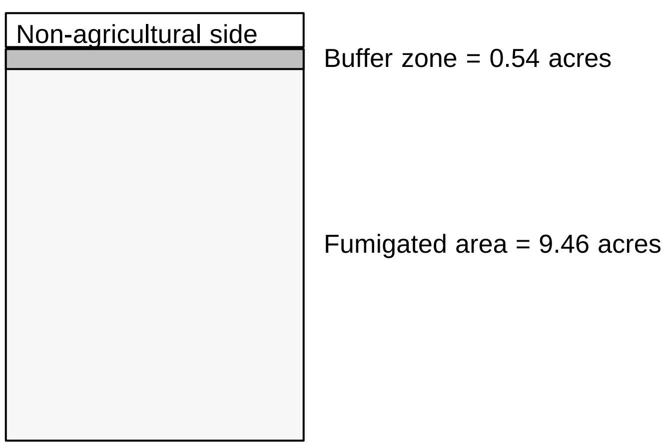
Shape A: Square field (660 ft. x 660 ft.)



Shape B: Rectangular field (466.7 ft. x 933.4 ft.]



Shape C: Rectangular field (933.4 ft. x 466.7 ft.)



Note: Each field is 10 acres

Table 5: Non-Methyl Bromide Fumigated Acreage as a Percentage of Total

Type	Shape A (square)	Shape B rectangular (long side non-ag)	Shape C rectangular (short side non-ag)
One non-agricultural border			
Ten-acre field	7.6	10.7	5.4
Ten-acre field (bed)	15.2	21.4	10.7
Fifty-acre field	3.4	4.8	2.4
One hundred-acre field	2.4	3.4	1.7
Two contiguous non-agricultural borders			
Ten-acre field	14.6	15.5	15.5
Ten-acre field (bed)	28.0	29.8	29.8
Fifty-acre field	6.7	7.1	7.1
One hundred-acre field	4.7	5.0	5.0
Two parallel non-agricultural borders			
Ten-acre field	15.2	21.4	10.7
Ten-acre field (bed)	30.3	42.9	21.4
Fifty-acre field	6.8	9.6	4.8
Three non-agricultural borders			
Ten-acre field	21.6	20.2	25.8
Ten-acre field (bed)	40.8	38.3	48.9
Fifty-acre field	9.9	9.3	11.8
One hundred-acre field	7.1	6.7	8.4
Four non-agricultural borders			
Ten-acre field	28.0	29.8	29.8
Ten-acre field (bed)	51.4	55.1	55.1
Fifty-acre field	13.1	13.9	13.9
One hundred-acre field	9.4	9.9	9.9

Table 5 highlights three key aspects of the 2001 DPR regulations. First, the relative impact of the use restrictions depends upon field size and shape. Second, the effect of the regulations on an individual grower will depend on the characteristics of the adjoining property, and the willingness of adjacent agricultural property owners to allow the buffer zone to extend onto their property. Third, the size of the buffer zone is determined by the method of fumigation.

Consider the importance of the field size and shape. In Table 5 we see that a grower with a fifty-acre square field (shape A) with one non-agricultural border must set aside 3.4% of his or her acreage as an inner buffer zone. At the same time, the buffer is 7.6% of the acreage for a ten-acre square field with one non-agricultural border. In general, a larger percentage of the acreage of smaller fields had to be set aside as buffer zones and could not be fumigated with MeBr.

It is also the case that the longer the side of the field bordering the non-agricultural use, the larger the percentage of total acreage that could not be fumigated with MeBr. In

Table 5, the rectangular field with the long side bordering the non-agricultural use (Shape B) loses the largest share of acreage.

Besides field size and shape, bed versus flat fumigation has a significant impact on the size of the buffer zone. This issue is of particular importance in Santa Barbara County, where almost 100% of the acreage was bed fumigated prior to the 2001 regulations. Ventura County also had a sizable amount of bed fumigation (about 10% of the fumigated acreage). Bed fumigation results in a larger share of non-fumigated acreage, due to the higher emission ratio chosen by DPR for bed fumigation. For instance, from Table 5 we see that for field shape A (i.e., square) with two parallel non-agricultural borders flat fumigation results in a buffer that occupies 15.2% of the field, whereas bed fumigation gives a buffer equal to 30.3% of the field.

Finally, as the number of sides with a non-agricultural use increases, acreage loss increases as a share of total acreage.

Table 6 reports the distribution of fields according to the number of sides where the inner buffer zone reduced fumigated acreage, referred to as a “binding side.” This information is not included for Santa Cruz County.

Table 6. Distribution of Fields by Number of Binding Sides

		Number of binding sides					
County	**Type**	**0**	**1**	**2**	**3**	**4**	**County totals**
Monterey	Number of fields	131	1	2	0	0	134
	Total acres	5,346	37	68	0	0	5,451
Orange	Number of fields	40	2	2	0	0	44
	Total acres	1,370	81	33	0	0	1,484
Santa Barbara	Number of fields	32	9	10	9	20	80
	Total acres	615	437	193	304	1,276	2,825
Ventura	Number of fields	80	10	5	4	0	99
	Total acres	5,026	521	305	132	0	5,984

Outer Buffer Zones

In contrast to inner buffer zones, the outer buffer zone could extend into all other property except occupied housing, schools, hospitals, convalescent homes, and other sensitive sites, if permission was obtained from the landowner, and if worker notification and other regulatory requirements were met. The restriction on time spent in the outer buffer zone was much less stringent, only limiting an individual to twelve hours in a twenty-four hour period. The minimum inner buffer zone was 50 feet, and the minimum outer buffer zone was 60 feet.

The effect of the outer buffer zone requirement on the acreage losses reported above depended upon the uses of nearby land parcels, and the distance of each parcel from the intended fumigation site. Occupied houses, hospitals, schools, and similar sensitive sites must be outside the outer buffer.

In addition, farmers were required to notify all property owners within 300 feet of the edge of the outer buffer zone. If these individuals requested at the time of the initial notification, the farmer was required to notify them again within 48 hours of the actual fumigation. We collected county data that allowed us to estimate the magnitude and distribution of the direct costs of this requirement, and the results are reported below.

V.2. Estimated Impacts of Buffer Zone Regulations

The actual acreage lost due to the DPR methyl bromide use regulations depended upon the size and shape of an individual field, as well as the use of adjacent parcels. Smaller fields lost a larger percentage of total acreage, holding other factors constant. Table 7 reports the field size distribution across counties from the collected workplans. Fields with more non-agricultural borders lost a larger percentage of total acreage, again, holding other factors constant. It is important to emphasize that these losses presumed that owners of adjacent parcels would always give permission for buffers to extend onto their property, when this was allowed by the regulation; in practice, there is no guarantee that this would have been the case.

Table 7. Field Size Distribution, by County

County	Type	Acres					
		< 10	10 to 24	25 to 49	50 to 99	100+	Total
Monterey	Number of fields	6	41	52	25	10	134
	Average acres per field	5.8	17.4	35.2	67.3	113.8	40.6
Orange	Number of fields	12	5	15	10	2	44
	Average acres per field	2.9	15.6	34.1	59.5	132	33.7
Santa Barbara	Number of fields	19	23	22	12	4	80
	Average acres per field	4.1	17.7	35.4	70.4	179.3	35.3
Santa Cruz	Number of fields	10	27	16	8	3	64
	Average acres per field	3.9	15.9	29.7	64	114.3	28.1
Ventura	Number of fields	9	15	28	27	20	99
	Average acres per field	5.4	16.8	37.8	68.6	138.6	60.4

The regulations imposed a number of other costs on agricultural producers. Designing a fumigation plan that complied with regulatory requirements was much more time-consuming than was the case prior to these regulations. The total time required to fumigate increased for many fields, which affected production planning and profitability. In the case of strawberries, for example, lengthening fumigation time shortens the harvest period for the previous year's crop, since it must be removed earlier in order to complete fumigation prior to the planting season. Notification requirements are quite time consuming, and can negatively impact neighbors' perceptions of agricultural activities. This perception may ultimately limit producers' freedom to operate according to best agricultural practices in still unforeseen ways.

The impact of the DPR use regulations on producers was unequal. Growers in areas with higher population densities were much more likely to be heavily impacted by the buffer zone, permission, and notification requirements. Growers with smaller fields faced a proportionately greater loss of fumigated acreage than growers with large fields. Growers who had to discontinue bed fumigation saw their costs rise dramatically.

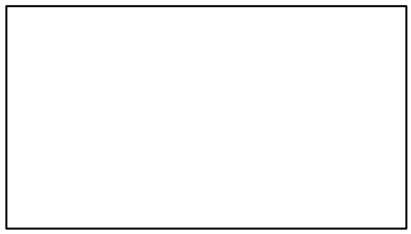
These potential effects have troubling implications regarding the impact of the use regulations across different population groups. To the extent that it is the small growers who farm small fields, small growers were disproportionately affected by the regulations. Further, the complexity of the regulations disproportionately increased the burden of regulatory compliance for less educated growers, or growers who are less than fluent in English. Language differences may also limit the ability of some growers and neighboring landowners and residents to communicate effectively. In turn, this may reduce the acreage that growers can fumigate if they are unable to secure permission to extend buffer zones into neighboring properties. Conversely, some neighbors may not understand fully their rights regarding notification and buffer zone permissions.

In order to evaluate the acreage losses due to the DPR regulations, we use a program developed by Leo Simon that determines the fumigation plan that maximizes acres fumigated, given the regulatory constraints. The nature of the fumigation problem does not lend itself to standard optimization. Instead, the code calculates the number of days required to fumigate the entire field according to the following procedure: On day one, begin fumigating the maximum distance away from any mandatory in-field inner buffers, referred to as ‘binding’ sides. If only one side is binding, then the program does strips back and forth, beginning on the other side of the field. If two adjacent sides are binding, it does L-shaped strips beginning along the other two sides of the field. If two opposite sides are binding, it does strips beginning from the center. With three binding sides, it begins in the center with an initial rectangle, then does u-shaped applications that move toward the three binding sides. If all four sides are binding, it completes rectangles, starting from the center of the field. If no sides are binding, it also completes rectangles, starting from the center of the field.

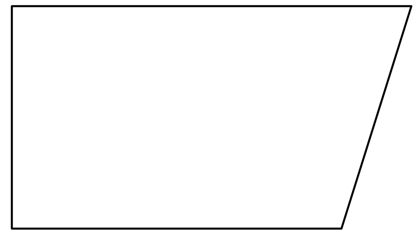
On the second day of fumigation (real time day 3), it begins on the strip where it finished the first day. This strip determines the inner buffer for the second day of fumigation, and hence the total acres that can be fumigated. It continues with this approach, each day completing the maximum acreage, until the field is completed. Based on information from growers and other industry members, we restrict total acreage fumigated to fifteen acres per day. This upper bound roughly reflects the worker exposure provisions included in the DPR 2001 regulations. Clearly, individual growers may exceed this limit, particularly if they are able to run more than one fumigation team. Overall, however, we have no information regarding whether or not individual growers actually fumigated more than fifteen acres per day, even if a larger number was specified in the workplan. Accordingly, we specified a consistent upper bound.

The fumigation optimization program cannot address all possible field shapes in its current form. It can analyze rectangles, right-angle triangles, and quadrilaterals with two right angles (as illustrated in Figure 2). It can also evaluate these shapes when a side is missing acreage on its interior, provided the missing acreage does not intersect one of the field's primary diagonals. However, it cannot evaluate one of these shapes when a corner of the field is missing (a "Utah"-shaped field). The other limitations of the program are that it considers a buffer to be binding for the entire length of a side, considers only one binding buffer width, regardless of the number of buffered sides, and considers only one application bloc per day, regardless of field size. Conceptually, it is possible to relax all of these restrictions; however, it is computationally expensive. Relaxing these restrictions would require extensive programming efforts. Appendix One reports the percentage of permit fields and acres analyzed by county.

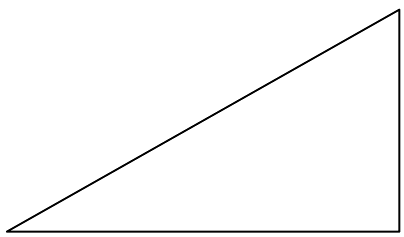
Figure 2. Field Shapes Included in Optimal Fumigation Simulations



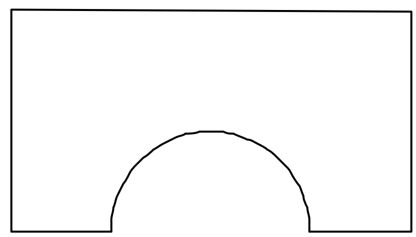
A. Rectangle



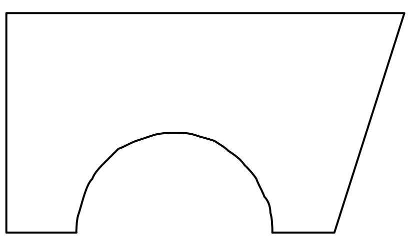
B. Quadrilateral with two right angles



C. Right angle triangle



D. Rectangle with interior acreage missing[1]



E. Quadrilateral with interior acreage missing[1]

[1] Rectangular interior missing acreage modeled as half-circle of the same acreage.

For Monterey, Orange, Santa Cruz, and Ventura counties, we specified the minimum inner buffer zone of fifty feet. This specification was largely consistent with the actual workplans; very few fields were required to have larger inner buffer zones. Unlike the other counties, a substantial share of Santa Barbara workplans specified minimum inner buffer zones that were larger than 50 feet, due in part to the use of bed fumigation in the county. In order to reflect the relatively more rigorous inner buffer zone decision process in Santa Barbara, we used the minimum buffer zone specified in the workplan. (See Appendix 1 for more information.)

We examined two different scenarios using the optimal fumigation program. In the first scenario, we included actual inner buffer zone restrictions as specified in the workplans, to the extent that these restrictions could be determined. We refer to a field side where the inner buffer zone reduces fumigated acreage as a "binding side," or a side with a binding restriction. We ran a second scenario where we assumed that the inner buffer zone was binding on all four sides. Under the 2001 DPR regulations, growers must obtain permission from neighboring landowners to extend the buffer zones onto their property. The second scenario illustrates how critical these permissions are to growers; comparing the two scenarios allows one to see how these permissions reduced acreage losses due to the inner buffer zone requirement. Except for cases where the grower owns the adjacent acreage, there is no guarantee that these permissions will continue to be granted. However, given available information, the importance of this uncertainty and its potential costs for growers cannot be estimated. Table 8 reports our findings.

Table 8. Fumigation Simulation Analysis

County	Field acreage	Actual restrictions: Buffer acres	Buffer/ field acres	Total fum. acres	Fum. days	Num. Buffered sides	Maximum restrictions: Buffer acres	Buffer/ field acres	Total fum. acres	Fum. days
Monterey										
Mean	25.38	0.37	2.1%	25.01	2.16	0.36	4.48	23.4%	20.90	2.04
Minimum	0.99	0.00	0.0%	0.99	1.00	0.00	0.78	10.9%	0.21	1.00
Maximum	77.48	2.71	33.3%	77.48	6.00	4.00	8.46	78.6%	69.02	5.00
Coeff. Variation	0.63	2.38	3.27	0.64	0.53	2.64	0.36	0.58	0.70	0.48
Orange										
Mean	27.76	0.30	2.4%	27.46	2.59	0.27	4.37	36.7%	23.39	2.32
Minimum	0.77	0.00	0.0%	0.77	1.00	0.00	0.74	10.2%	-0.01	1.00
Maximum	137.74	2.18	25.8%	137.74	10.00	2.00	14.00	100.9%	123.74	9.00
Coeff. Variation	1.20	2.22	2.58	1.22	0.90	2.31	0.73	0.77	1.29	0.89
Santa Barbara										
Mean	28.50	5.27	20.5%	23.24	2.15	1.62	11.78	47.7%	16.72	1.69
Minimum	4.08	0.00	0.0%	2.28	1.00	0.00	1.75	10.0%	2.28	1.00
Maximum	90.36	20.29	55.7%	90.37	6.00	4.00	25.13	66.3%	81.38	6.00
Coeff. Variation	0.85	1.46	1.15	1.00	0.65	1.17	0.63	0.29	1.26	0.85
Santa Cruz										
Mean	30.89	0.62	3.4%	30.27	2.50	0.57	6.10	25.9%	26.13	2.07
Minimum	3.10	0.00	0.0%	2.76	1.00	0.00	0.36	11.6%	1.61	1.00
Maximum	90.91	3.52	23.5%	90.91	7.00	4.00	25.13	48.1%	80.35	6.00
Coeff. Variation	0.93	1.83	1.97	0.94	0.76	1.91	1.25	0.50	1.02	0.81
Ventura										
Mean	48.97	1.57	3.5%	47.40	3.71	0.86	6.42	18.4%	42.56	3.54
Minimum	5.50	0.00	0.0%	5.50	1.00	0.00	2.11	8.1%	3.38	1.00
Maximum	136.10	10.06	24.3%	136.10	10.00	4.00	10.98	38.4%	125.12	9.00
Coeff. Variation	0.73	1.96	1.93	0.74	0.67	1.73	0.41	0.48	0.78	0.66

Santa Barbara shows the largest acreage losses by far of the five counties, with inner buffer zones accounting for 20% of total field acreage under the actual 2001 regulations depicted in the workplans. On average, Santa Barbara fields had the largest number of field sides where the inner buffer zone resulted in acreage losses, 1.62. Acreage losses in other counties averaged between 1.9% (Monterey) and 3.5% (Ventura). Other counties all averaged less than one side per field where the inner buffer zone resulted in acreage losses.

By comparing acreage lost to inner buffer zones under actual and maximum restrictions, we can obtain some sense of what share of differences across counties is due to differences in field shapes, and what share is due to differences in the proximity to residential areas and sensitive sites. Larger increases in the percentage of acreage lost to inner buffer zones under the maximum restrictions suggests that field shape and size is more important than proximity to non-agricultural land. By this measure, the effect of proximity was smallest in Ventura. Ventura has substantially larger fields on average than the other counties, which reduces the share of field acreage lost to a buffer zone of a specified width. The average number of binding sides under the actual restrictions also provides a measure of proximity, although it does not account for the different effect of a given inner buffer restriction on fields of different sizes.

One shortcoming of our analytical procedure is that we cannot assess the costs incurred by growers who had to abandon fields for strawberry production, due to binding buffers. A second is that buffer restrictions are likely to be most complex for the oddly-shaped fields that cannot be analyzed using the program. A third shortcoming is that we are reliant on the quality of data from permits and work site plans. Data quality varies widely by county, as discussed in Appendix 1. Santa Cruz county, which has the most complete information available, also experienced the highest costs due to the restrictions. However, since Santa Cruz is also characterized by the smallest average field size across counties and is highly urbanized, we cannot simply project costs across all counties. These limitations do suggest, however, that our estimates of acreage losses are surely a lower bound for each county.

V. 3. Foregone Sales of Processing Strawberries

On average, over the past four years (1997-2001), approximately 417 million pounds of California strawberries were sold to processors (see Table 1). This represents about 30% of annual strawberry production. Deliveries to processors as a percentage of production vary by region, with the southern region of the state typically delivering a higher percentage to processing than the northern part of the state. In 2001, the Orange County and Oxnard areas sold 54% and 30% of the crop, respectively, to the processing market. In the same year, the Santa Maria and Watsonville areas sold 37% and 7% of the crop, respectively, to the freezer market.

A small percentage of the processing sales are second-year berries, but the majority of processed sales are from end-of-season berries. As warmer temperatures diminish fruit quality (firmness and size), growers usually switch to processing sales. Eventually, they remove the plants in order to prepare the ground for the next crop. However, this is not an issue for growers who double crop (say with vegetables), which is a practice more common in the northern part of the growing region, especially in the Watsonville area.

The 2001 DPR regulations disrupted the normal pattern of sales to the processing market because the regulations significantly lengthened the fumigation period. The longer fumigation period affected the ability of producers to sell into the freezer market because they had to remove the plants earlier than they would have done to maximize profits. Some growers in the southern part of the state lost up to four weeks of processing market sales. Assuming 2,500 pounds per acre per week of processing berries at 30.6¢ per pound,[1] the estimated revenue loss is $765 per acre per week. After harvest costs (of about 14¢ per pound), the net profit on these sales would be approximately $415 per acre per week or 16.6¢ per pound.

For the purposes of this report, we interviewed a number of growers and most of them reported that they lost production at the end of the season due to the new DPR fumigation regulations. Data from the Processing Strawberry Advisory Board of California (see Table 1) shows a decline in the 2001 freezer volume to 338.9 million pounds (or 25.7% of production). This is below the previous five-year average of 421.7 million pounds (or 30.5% of production). We estimate that a large portion of the decline of 82.8 million pounds was due to the DPR regulations. We estimate that the DPR regulations resulted in foregone processing sales of about 62.75 million pounds of berries, representing a total loss of approximately $10.4 million for California growers. This volume represents an estimated loss of approximately one week's production, on average, for every acre in the state. This is likely to be a conservative estimate, as some growers lost much more than one week, especially those in the southern part of the state. Thus, these losses were unequally distributed across growers.

V.4. Costs of Additional Fumigation Days

The 2001 DPR regulations lengthened the required time period for fumigation for all growers in the state using methyl bromide. As illustrated above in Section V.3, the extent to which the fumigation period was extended varied by field shape, location, pounds of MeBr applied, fumigation method, etc. In many cases, the length of time required for fumigation was extended by a factor of three or four, and this was a significant burden on growers. Prior to the 2001 regulations, a grower with 40 acres may have fumigated in 1 or 2 days, but after the regulations were implemented, this same task took 5 or more days.

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[1] The average field price of processing berries was 30.6¢ per pound in 2001 according to the California Processing Strawberry Advisory Board's 2001 Annual Report.

Ironically, lengthening the fumigation period exposed workers to greater risk of accidental exposure to methyl bromide, as accidents usually happen when the equipment is being readied to bring to and from the field. However, this is not an issue that we investigated, nor do we have data pertaining to such accidents. Suffice to say that the longer fumigation period could have had unintended consequences for worker exposure to methyl bromide.

The longer fumigation period resulted in unavoidable costs for strawberry growers. Total fumigation costs per acre increased as a result of the diseconomies of fumigating relatively small pieces of land each day. The diseconomies were more costly per acre for the smaller fields. For instance, in Santa Barbara County it took one grower 9 days to fumigate a 9-acre field in 2001. In the same county, it took another grower the same number of days to fumigate a 40-acre field.

Based on interviews and budget data, we estimate that non-chemical fumigation costs increased by at least 40% due to the longer fumigation period. This translates into a cost increase of about $400 per acre. In all likelihood, this is a conservative estimate of the higher costs. The total industry impact is estimated to be have been about $10 million, for 25,000 acres.

V.5. Costs of Switching from Bed to Flat Fumigation

Due to regulatory specifications of emissions ratios, buffer zone requirements were much more onerous for “bed” fumigation, where only the raised beds are fumigated. As a result, some growers had to switch to “flat” fumigation so they could fumigate most of their field. Flat fumigation is much more expensive, at least $1,000 per acre more than bed fumigation. This regulation benefited pesticide applicators, since most growers did not have the equipment necessary for flat fumigation and as a result they had to hire custom applicators.

Growers in Santa Barbara County were most affected by this regulation. There are more than 3,000 acres of strawberries grown in Santa Barbara County and this acreage was virtually all bed fumed prior to the 2001 DPR regulations. About 20% of these acres had no choice but to switch from bed to flat fumigation in 2001, moving to commercial applicators and increasing application costs for county producers by about $700,000. The switching costs in Ventura County are estimated to be about $500,000, which represents costs associated with switching about 500 acres. In Monterey County, an estimated 700 acres were switched, at a cost of $700,000 million. For Santa Cruz County, we estimate a switching cost of $300,000, and for Orange County, we estimate a switching cost of $200,000.

Total switching costs are therefore estimated to be approximately $2.4 million for 2001.

V.6. Notification Costs

Overall, our analysis of work site plan data indicates that notifications, and notification costs, per acre vary substantially across fields. In general, smaller fields tend to have higher notification costs per acre. Fields that are near urban areas or rural residential developments have a larger number of notifications and higher notification costs per acre, on average. In this section, we evaluate the total number of notifications per field, including individuals contacted for permission to extend inner and outer buffers onto their property. The summary data are shown in Table 4, and some of the data underlying Table 4 are displayed in Figures 2 through 5, by county. The estimated notification costs range from $1.67 per acre in Santa Barbara County to $9.66 per acre in Orange County. However, the Orange County estimates are based on a relatively small sample, so those estimates may not accurately reflect average costs per acre for all fields, and the Santa Barbara estimates exclude pre-fumigation 48 hour notices, so that those estimates underestimate per acre costs (See Appendix 1).

While we report both per field and per acre costs, per acre costs are the most appropriate measure of economic costs. Other variable costs, such as plants and fertilizer, are borne on a per acre basis, and strawberry revenues are a function of per acre yields. When we calculate averages per acre, it is important to remember that we calculate these figures by computing the average per acre *for each field* first, then averaging the results for each field. This number better represents the effects on the average producer than would calculating the total number of notifications for the county, for example, and then dividing it by the total acres in the county.

We report information regarding the number and costs of notification requirements by county. We spoke to growers regarding the average time notifications required. Based on this information, the average notification requires thirty minutes due to travel time, notice preparation, multiple trips to find the neighbor at home, etc. We valued the management/supervisor labor used for conducting notifications at $20 per hour, or roughly twice the cost of field labor. Together, these values indicate that the average notification costs $10. We exclude other costs, such as mileage and copying costs.

One difficulty regarding this analysis was that not all counties require growers to report individual notifications, or the number of notifications required. Ventura and Orange counties require simply that growers indicate whether or not any notifications were required, although some growers do report the number of notifications, such as the Orange county grower who was required to notify 253 individuals in order to fumigate one fifty-acre field. Of course, permissions for the extension of inner and outer buffers into adjoining properties provide some information, but do not allow us to infer the total costs of notification, due to the requirement that residents within 300 feet of the outer buffer zone be notified.

Monterey

In Monterey County, fields applying methyl bromide ranged in size from 4 to 153.5 acres, with an average field size of 40.68 acres. 90% of fields applying methyl bromide provided at least one initial notification. Overall, fields averaged 8.6 notifications apiece, or 0.30 notifications per acre. As seen in Figure 4, there was no clear pattern in the relationship between field size and the number of notifications per acre.

Orange

In Orange County, 17% of fields did not apply methyl bromide. Within the remaining 83%, only 25% of field work plans reported the number of notifications made. For this 25%, the average number of notifications was 76.3. The average includes three fields with 253, 135, and 119 notifications, respectively. Even if we assume that all of the non-reporting fields to which methyl bromide was applied did not have to notify anyone, the average number of notifications for fields applying methyl bromide was 19.0, with an average cost per field of $190. The average cost per acre is $0.72 for all fields using methyl bromide, and $2.88 per acre for the seven reporting fields. Any difference between reporters and non-reporters is not explained by significant differences in average field size, since the seven reporting fields averaged 39.4 acres, and all methyl bromide fields averaged 41.7 acres. It may be the case that the number of notifications is biased upward by the three reported fields with over one hundred notifications. Based on the available information, we can conclude only that averaging the notification costs incurred by reporting fields over all fields using methyl bromide represents a lower bound on the average notification costs per field and per acre. Due to the small share of reporting fields, we do not conduct any further analysis.

Santa Barbara

In Santa Barbara, fields applying methyl bromide ranged in size from less than an acre to 159 acres. 58% of these fields provided at least one initial notification. Smaller fields tended to provide more initial notifications, as seen in Table 9. These results do not include 48-hour notifications.

Santa Cruz

Santa Cruz County has a wide variance in field size and notification costs. Smaller fields tend to have relatively more notifications, as demonstrated by Table 9. In the figure, costs per acre are reported by field size, from smallest to largest field. The graph shows that there is a downward trend, so that larger fields have lower costs per acre.

Ventura

Like Orange County, Ventura does not require that growers report the number of notifications per field. Instead, they simply report whether notification was required. Again, we cannot conduct a detailed analysis of notification costs. Unlike Orange County, there is no clear suggestion that notification costs may be higher than average for fields that report the number of notifications. However, the available observations suggest that smaller fields had higher notification costs per acre, as shown in Table 9.

Table 9. Average Notification Costs, by County: 2001

Type	Monterey	Santa Barbara*	Santa Cruz
Average field size	40.61	32.07	28.26
Average number of notifications per field	11.02	4.43	8.60
Average number of notifications per acre	0.30	0.19	0.76
Average notification cost per field	$110.20	$44.00	$86.00
Average notification cost per acre	$3.00	$1.92	$7.63

Source: estimated from individual fumigation permits collected from County Agricultural Commissioners.
** Santa Barbara includes only initial notifications, and does not include 48-hour pre-fumigation notifications.*

The overall notification cost was estimated by weighting the individual county estimates by production. This generated an average cost of about $5 per acre, or $125,000 for the state.

VI. Methyl Bromide Alternatives: Field-Level Analysis

Rather than incur the additional costs of complying with the DPR methyl bromide regulations, growers may choose to use other treatments. Alternatively, growers may use other treatments on strawberries planted in the buffer zones mandated by the DPR regulations. We focus on the alternatives that are currently available to California growers: chloropicrin, metam sodium, Inline and Telone C35 (the latter two are formulations of 1,3-D). At the field level, using alternative treatments may affect profits in two primary ways: affecting yield, and affecting costs. The effect of alternatives on yield will depend on whether or not the strawberry plants face disease or pest pressures. When evaluating these alternatives, it is important to remember that there is no guarantee that strawberry growers will be able to use these treatments, due to current (1,3-D) and potential (chloropicrin) DPR use regulations. New regulations may also increase costs, for reasons similar to the reasons the methyl bromide regulations increased costs.

VI.1. Yields

To date, scientific field trials indicate that in the absence of disease pressures, yields with chloropicrin, Inline, or Telone C-35 are not statistically different (Nelson et al.). This finding is supported by field trials in other growing areas, including North Carolina and Spain (Ferguson et al.; Lopez-Aranda et al.). One must be cautious when extrapolating across growing areas; even within California, researchers and growers have noticed efficacy differences across regions. In addition, yield results are sensitive to chemical and water application rates. These results may overstate yields from alternatives; the plants used in the studies were grown in nurseries that fumigated with methyl bromide, which may have increased plant vigor. Currently, trials are underway that use alternative treatments throughout the multi-year nursery stage, in order to assess the importance of this effect. Another concern is the efficacy of these alternatives against diseases and pests that reduce yields. Producers face a learning curve regarding the use of these alternatives, especially when drip-applied. Finally, the transferability of the results from scientific trials to commercial fields, especially commercial fields in other regions, may be imperfect.

The regulatory environment suggests that these alternatives may not be freely available for use by strawberry producers. Chloropicrin is currently being monitored by DPR in order to determine whether additional restrictions are necessary. If any such regulations are enacted, the yields under chloropicrin may be reduced if application rates are reduced. Similarly, eligible acreage may decline if new buffer zone restrictions are imposed.

There are three important regulatory considerations that may limit the use of 1,3-D as an alternative: township caps, the buffer zone, and the maximum application rate. The recently revised product stewardship arrangement between DPR and Dow Chemical rations the use of 1,3-D products on a township basis. According to Carpenter, Lynch, and Trout, this restriction may be binding in some townships under the methyl bromide ban. Based on the available information from permits, it is impossible to assess whether this restriction affected growers' fumigation choices under the 2001 DPR regulations. The township caps have recently been revised. Use in a given year may exceed the previous 90,250-pounds per year cap, provided that use in 1995-2001 was under the cap. Essentially, DPR is allowing townships to draw down "banked" applications. Importantly, the new regulation does not allow for increased applications above an average of 90,250-pounds per year for the period from 1995 to the present (DPR, January 30, 2002). Hence, the analysis by Carpenter, Lynch, and Trout will certainly apply in the long term; at best, townships that had used no 1,3-D previously will be able to double their usage for five years, or extend a smaller increase inσ usage over a longer period of time.

DPR's August, 2001, suggested permit conditions for 1,3-D suggest a minimum buffer zone of 100 feet. In many, if not most, cases, this eliminates 1,3-D as a buffer zone fumigant. The suggested permit conditions also specify a maximum application rate of 334 pounds per acre for soil-injected Telone C35. This rate may be low enough to reduce the efficacy of 1,3-D for controlling pathogens in strawberries. For example, in the cost analysis described below Telone C35 was applied at a rate of 400 pounds per acre. Hence, there is a strong possibility that these field trial results overstate the actual economic value of this alternative under existing regulatory constraints.

VI.2. Weeding and Fumigant Costs per Acre

We evaluate costs per acre in terms of the cost of the actual chemical and the effect on the cost of hand weeding based on a study by Steve Fennimore and Rachael Goodhue (See Appendix 4). Of course, an important caveat regarding this analysis is that we use current chemical prices. We ignore differences in application costs, and other differences. For example, drip applications of fumigants require stronger, more expensive tubing and other equipment than simple drip irrigation does. Drip applications are also more management-intensive, which may increase costs. Table 10 reports weeding times, materials costs and weeding costs for each treatment addressed in the study. The same information is reported graphically in Figure 3.

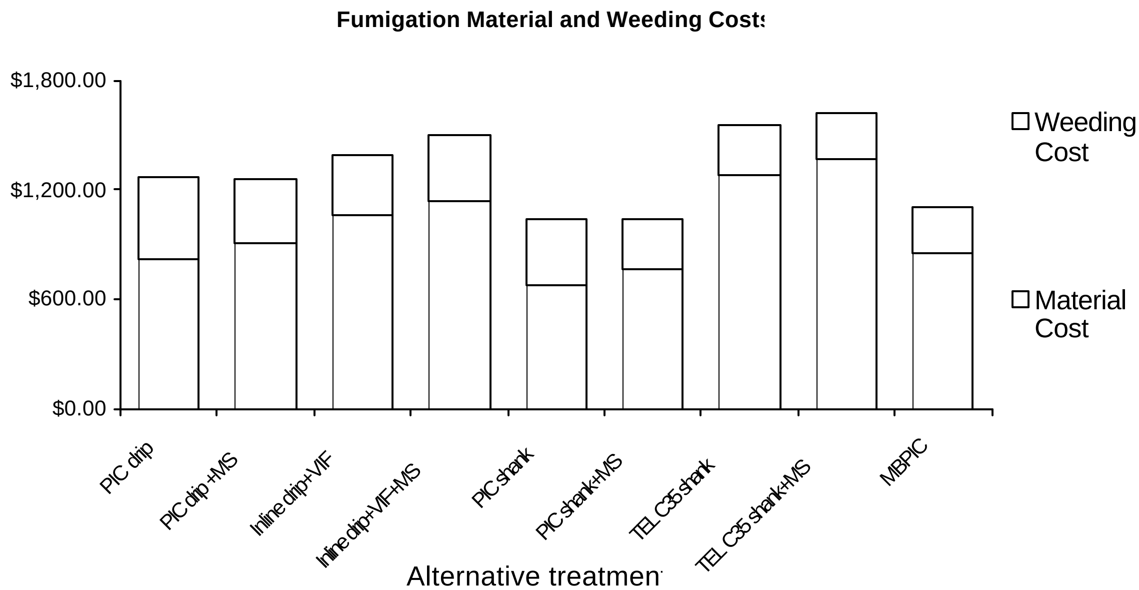
Table 10: Costs Per Acre

Fumigant	Fumigant cost	Tarp cost	Weeding cost	Total cost
PIC drip	$559.45	$264.86	$447.43	$1,271.73
PIC drip+MS	$642.37	$264.86	$349.87	$1,257.10
Inline drip+VIF Tarp	$525.16	$532.95	$331.11	$1,389.22
Inline drip+VIF Tarp+MS	$608.08	$532.95	$357.38	$1,498.41
PIC shank	$480.00	$205.00	$360.19	$1,045.19
PIC shank+MS	$562.92	$205.00	$269.21	$1,037.13
TEL C35 shank	$1,078.00	$205.00	$270.14	$1,553.14
TEL C35 shank-MS	$1,160.92	$205.00	$259.83	$1,625.75
MBPIC	$650.00	$205.00	$248.57	$1,103.57

Source: Fennimore and Goodhue
**Labor cost/hour is $9.38. Obtained from the University of California Cost and Returns study for the Oxnard Plain, 2001.*

Shank-applied chloropicrin had slightly lower weeding and material costs per acre than did the methyl bromide/chloropicrin control plot. All other applications had noticeably higher costs. Fumigation and weeding account for 20 to 38% of total cultural costs depending on region, so these cost differences are not insignificant, especially given the factors omitted from our analysis. Note that the experimental application rate for Telone C35 exceeds the regulatory maximum in California. Thus, these results may overstate the efficacy of Telone under actual field conditions. They may also overstate the economic viability of Telone, although there exists the possibility that reduced materials costs may offset increased weeding costs. When one considers the control of other pathogens, however, this scenario is less likely.

Figure 3. Costs of Alternative Treatments



Due to differences in soil, microclimates, pesticide regulations and other factors, it is unlikely that one alternative will be suitable for all growers. Accordingly, we expect that there will be some increase in costs per acre on average. There will be variations in the cost increase among growers, and possibly across production regions. Overall, we anticipate that over half of all acreage will be fumigated with chloropicrin with or without metam sodium. On average, we predict a 15-20% increase in fumigation material and labor costs per acre, provided that no additional regulations are enacted, and that material prices and wages do not change substantially.

VI.3. Production Risk

One unexamined factor that may affect profitability and grower adoption of alternatives is the variability of the efficacy of different treatments. For example, based on field trial data, metam sodium is not cost-justified as an additional treatment in conjunction with shank-applied Telone C35, or Inline using a VIF tarp. It is weakly not cost-justified as an additional treatment in conjunction with either drip- or shank-applied chloropicrin. However, chloropicrin has highly variable weed control, and the cost difference is small enough that growers may choose to use metam sodium in conjunction with chloropicrin in order to reduce the probability of very high weed populations and weeding costs (Fennimore and Goodhue).

VII. Other Regulatory Impacts

VII.1. Implications for Competitiveness of California's Strawberry Industry

The methyl bromide use regulations increased the costs of producing strawberries in California. The effect on the retail price of fresh strawberries depends on the extent to which imports compensate for any reduction in domestic production. Producers in Mexico, China and elsewhere are not subject to the same environmental regulations as are California producers. An increase in imports will make it difficult for California producers to recoup cost increases from complying with the regulations. Potentially, consumers could be unaffected; the only change would be the location where the strawberries are grown. Currently, imports equal roughly 10% of California's annual production. The majority of imports are from Mexico.

Table 11. United States Strawberry Imports (1997-2001)

	1997	1998	1999	2000	2001*
Fresh					
Mexico	13,744	25,358	42,201	33,117	29,183
All others	735	1,018	800	1,463	290
Frozen					
Mexico	26,622	22,447	37,316	30,583	24,152
All others	1,047	2,134	3,405	4,791	14,699

Source: U.S.D.A.
In metric tons
** 2001 numbers reflect activity through September only*

VIII. Conclusions and Recommendations

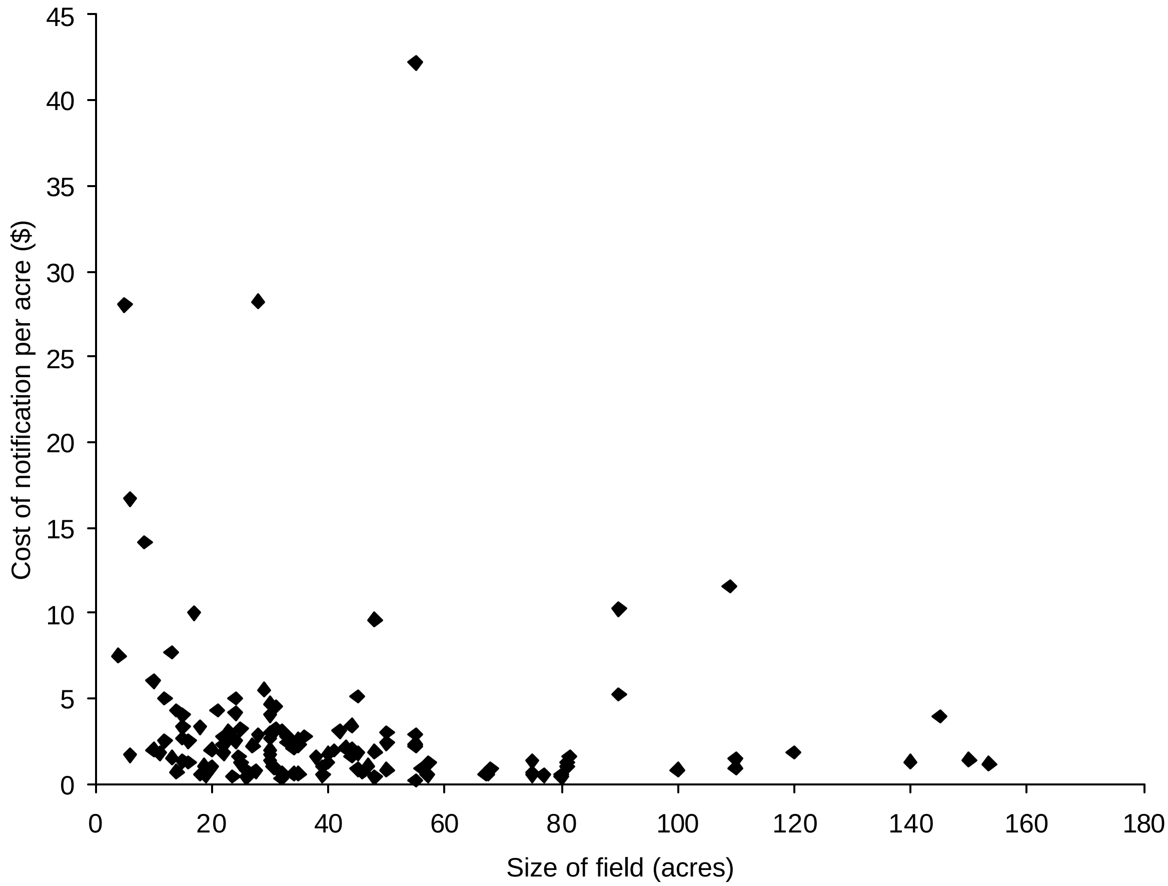
Our study concludes that the costs of the 2001 DPR regulations to growers in the strawberry industry are significant. We estimate that they exceeded $25 million for the 2001 season. The two most significant components were the reduction in the volumes marketed for processing, due to the increased time needed for fumigation for the following season, and increased fumigation costs.

We did not survey all growers to find out about their full set of adjustments to the DPR regulations. For instance, we have only anecdotal evidence concerning fields going out of production because it was not worth paying the increased cost of fumigation, or because the inner buffer zone requirements were too restrictive. Also, our estimates of increased fumigation costs do not take into account whether some growers' costs rose more than predicted by the MATLAB program we used for optimizing fumigation. To the extent that growers found it difficult to implement a plan consistent with the DPR regulations, or difficult to arrange a fumigation schedule, we have understated impacts on those growers.

Notification costs for growers are a relatively small portion of the total cost to the industry that we have estimated. However, there are additional costs in each county, as the agricultural commissioners' offices must implement the DPR regulations. We have no data on the time devoted to complying with the DPR regulations in each county.

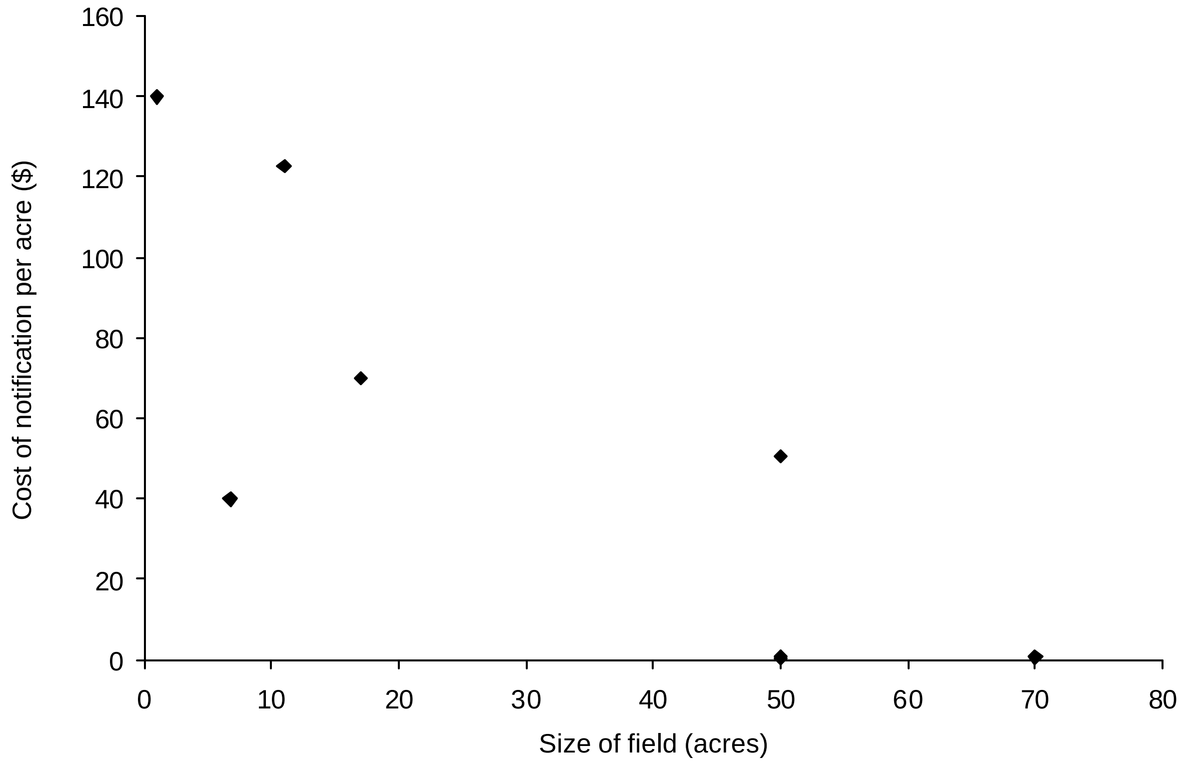
Finally, our study shows that full understanding of the adjustments by growers to such regulations, and a complete enumeration of the distribution of costs across growers in different regions and different size categories will require a survey.

Figure 4. 2001 Estimated Notification Costs, Dollars per Acre: Monterey County



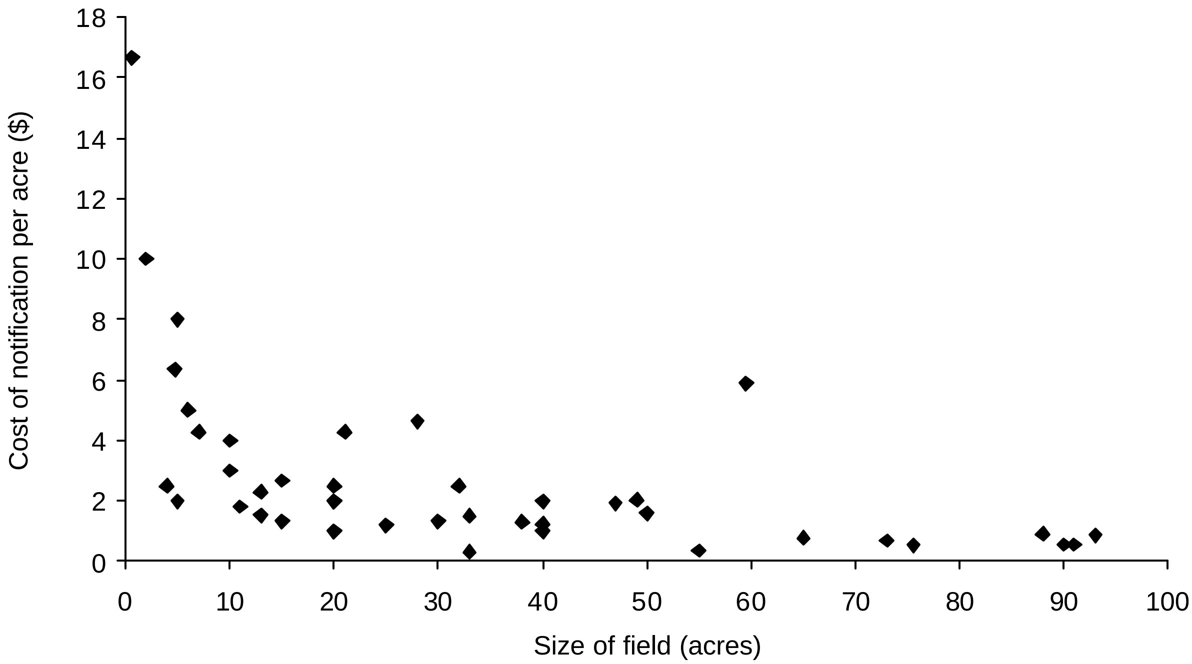
Source: See Table 4.

Figure 5. 2001 Estimated Notification Costs, Dollars per Acre: Orange County



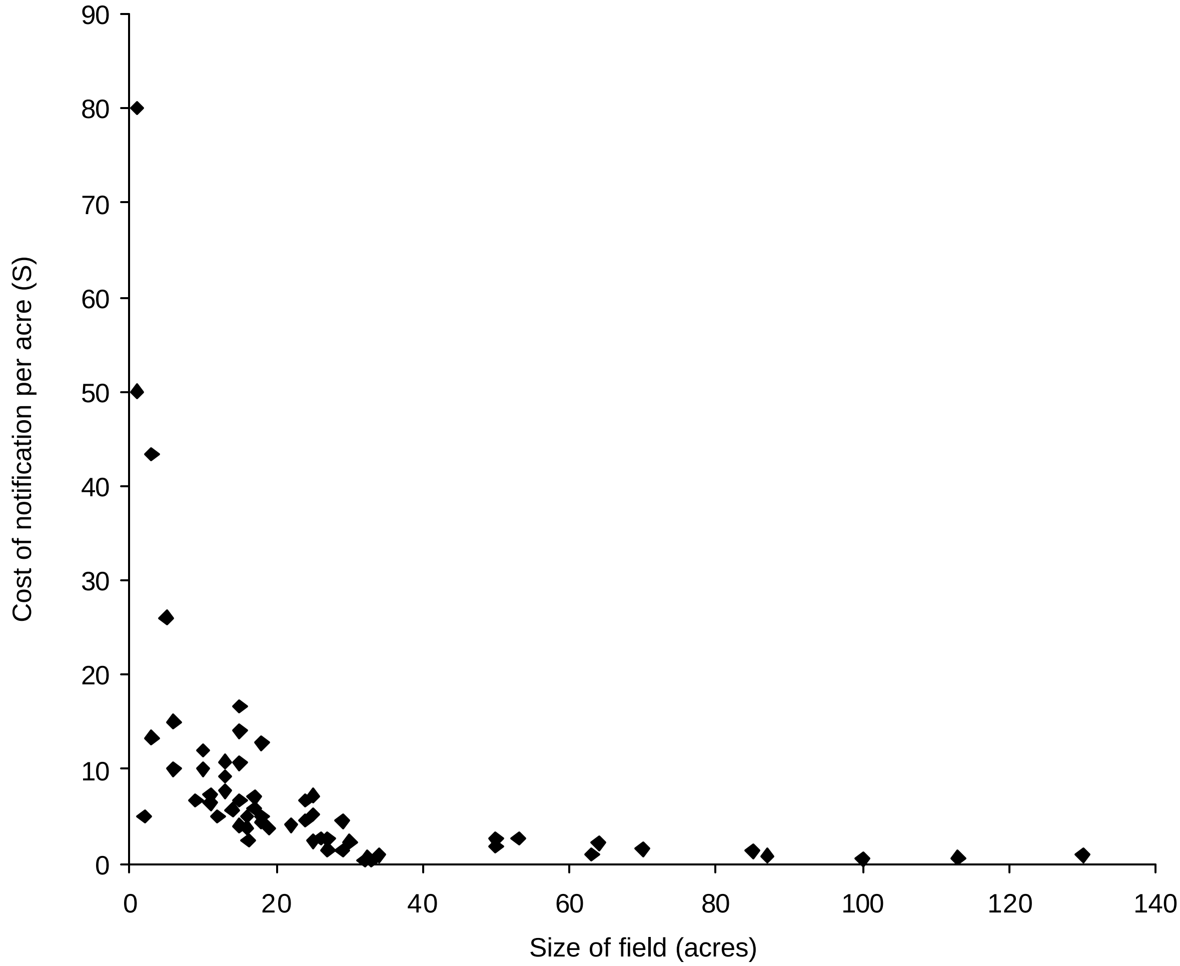
Source: See Table 4.

Figure 6. 2001 Estimated Notification Costs, Dollars per Acre: Santa Barbara County



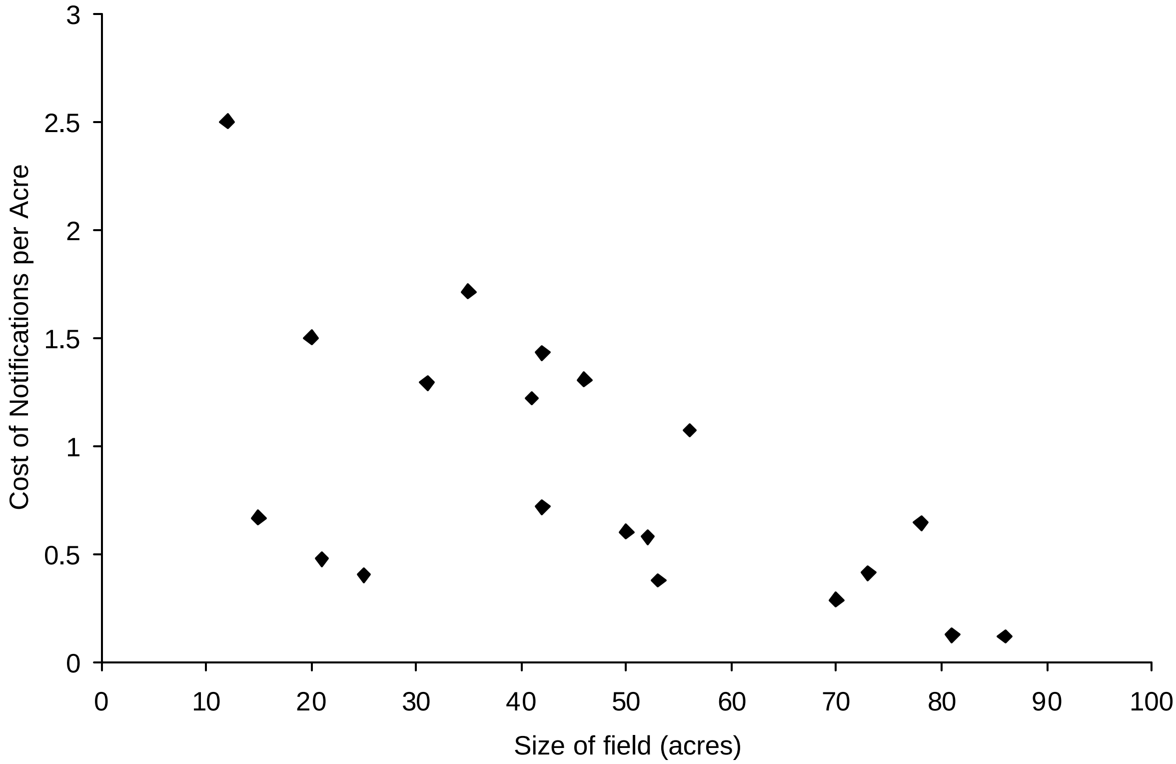
Source: See Table 4.

Figure 7. 2001 Estimated Notification Costs, Dollars per Acre: Santa Cruz County



Source: See Table 4.

Figure 8. 2001 Estimated Notification Costs, Dollars per Acre: Ventura County



Source: See Table 4.

REFERENCES

California Department of Food and Agriculture "California Fruit and Nut Crops." 2001 Agricultural Resource Directory., page 76. http://www.cdfa.ca.gov

Carpenter, Janet, Lori Lynch and Tom Trout. "Township Limits on 1,3-D Will Impact Adjustment to Methyl Bromide Phase-Out." *California Agriculture*. 55(3):12-18.

Fennimore, Steven and Rachael Goodhue. "Weeding Time Estimates in Commercial-Scale Fumigant Evaluations at Oxnard, CA." University of California, Davis. Working paper, 2001. 2 pages.

Ferguson, L.M. et al. "Alternative Soil Treatments for Strawberry in the Southeastern United States." Proceedings of the 2001 Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, November 5-9, 2001. P.42-1 to 42-4.

Foreign Agricultural Service: World Horticultural Trade & U.S. Export Opportunities - December 2001 United States Dept. of Agriculture. Available: http://www.fas.usda.gov/htp/horticulture/berries/sberry01.pdf [26 June 2002].

Lopez-Aranda, J.M. et al. "Chemical and Non-Chemical Alternatives to MD Fumigation of Soil for Strawberry. 2000-2001 Results." Proceedings of the 2001 Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, November 5-9, 2001. P.40-1 to 40-4.

Nelson, M. et al. "Results from 2001 USDA IR-4 MBA Field Trials in CA and FL Strawberries." Proceedings of the 2001 Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, November 5-9, 2001. P.43-1 to 43-5.

Processing Strawberry Advisory Board of California. 2001 Annual Report.

1997 Census of Agriculture: Geographic Area Series, Volume 1, 1A, 1B, 1C [machine-readable data file] / United States Dept. of Agriculture, National Agricultural Statistics Service. Washington, D.C.: The Service [producer and distributor], 1999. Available: http://govinfo.library.orst.edu/stateis.html [26 June 2002].